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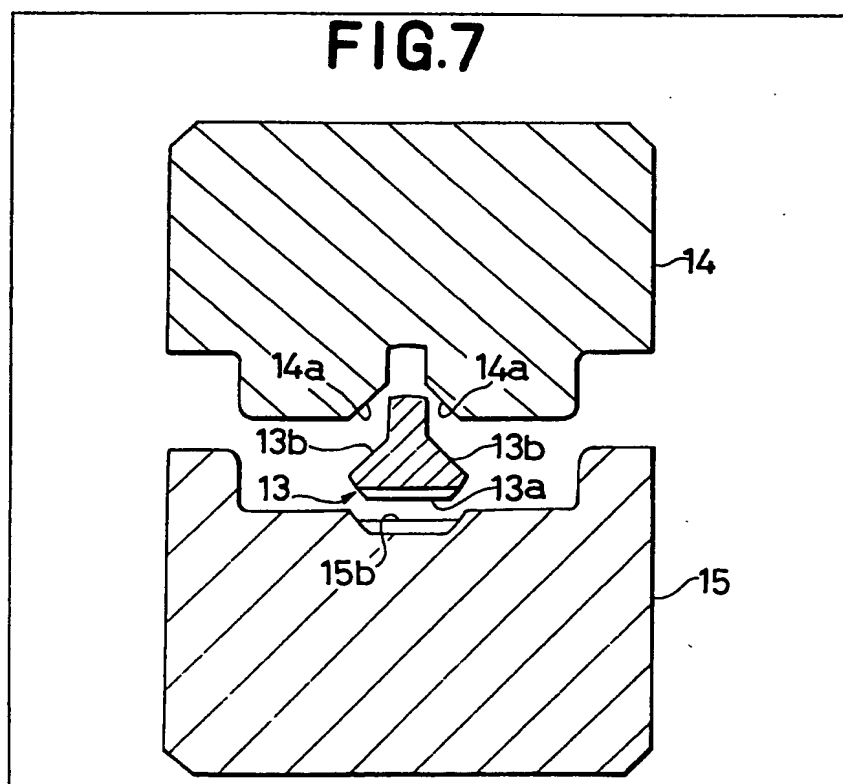
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(54) Manufacturing toothed racks

(57) A method for manufacturing toothed racks, which are suitable for producing variable ratio racks, comprises a first working step for the preliminary or rough forming of rack teeth (13a) which resemble the shape of final rack teeth to be formed, and a second working step in which a

forging operation is used to finish the rack teeth formed in the first step into their final shape by using upper and lower dies (14, 15) which have the configuration suitable for forming the rack teeth to be produced. The first working step may be a forging operation, or a cutting operation, possibly preceded by a forging or an extrusion operation.



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FIG.1

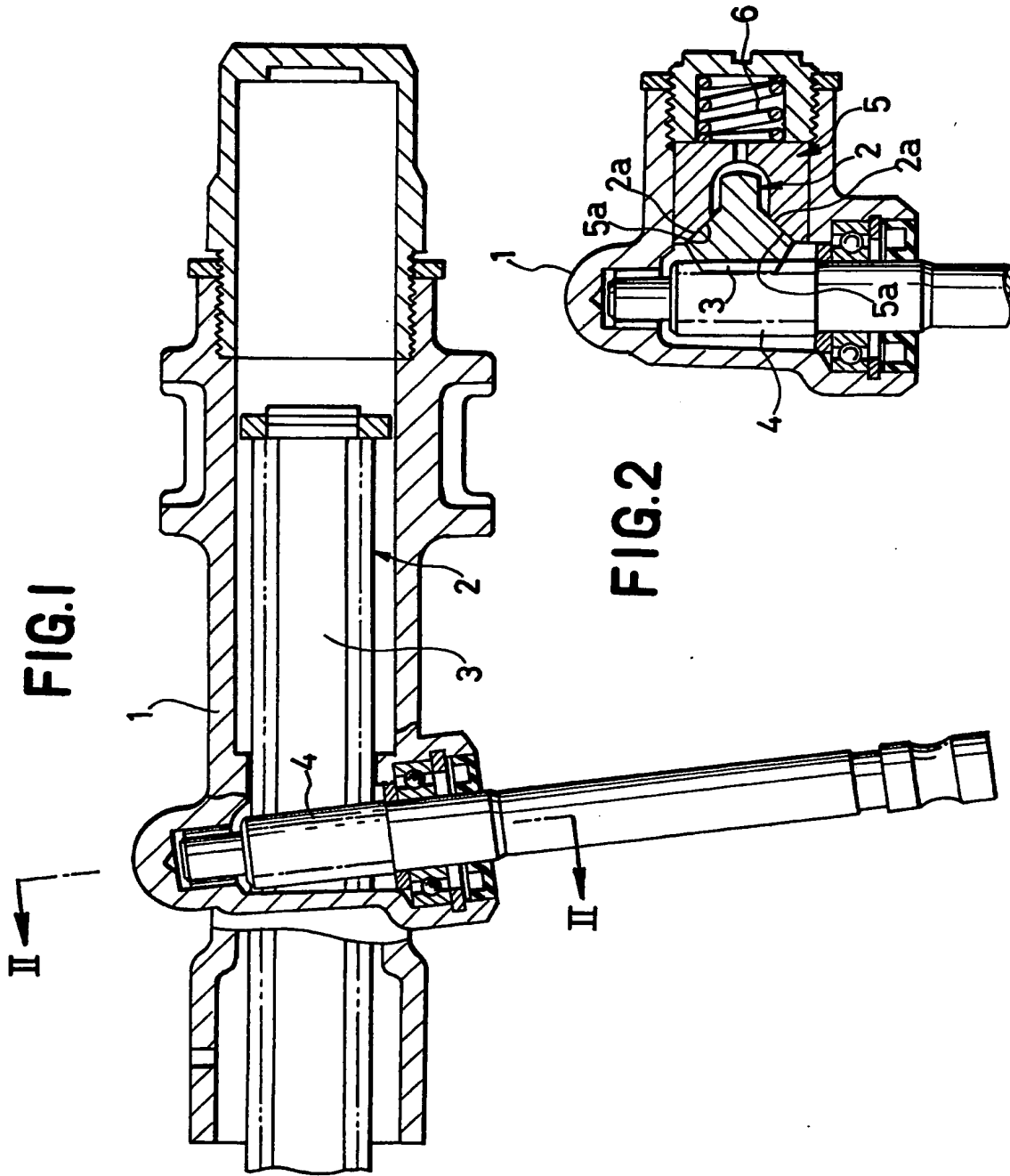
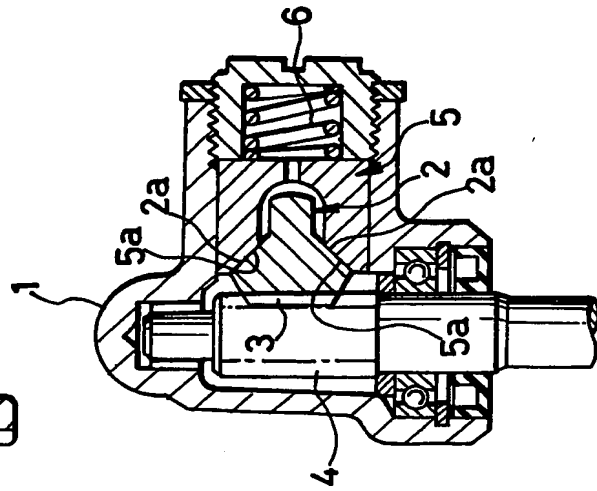


FIG.2



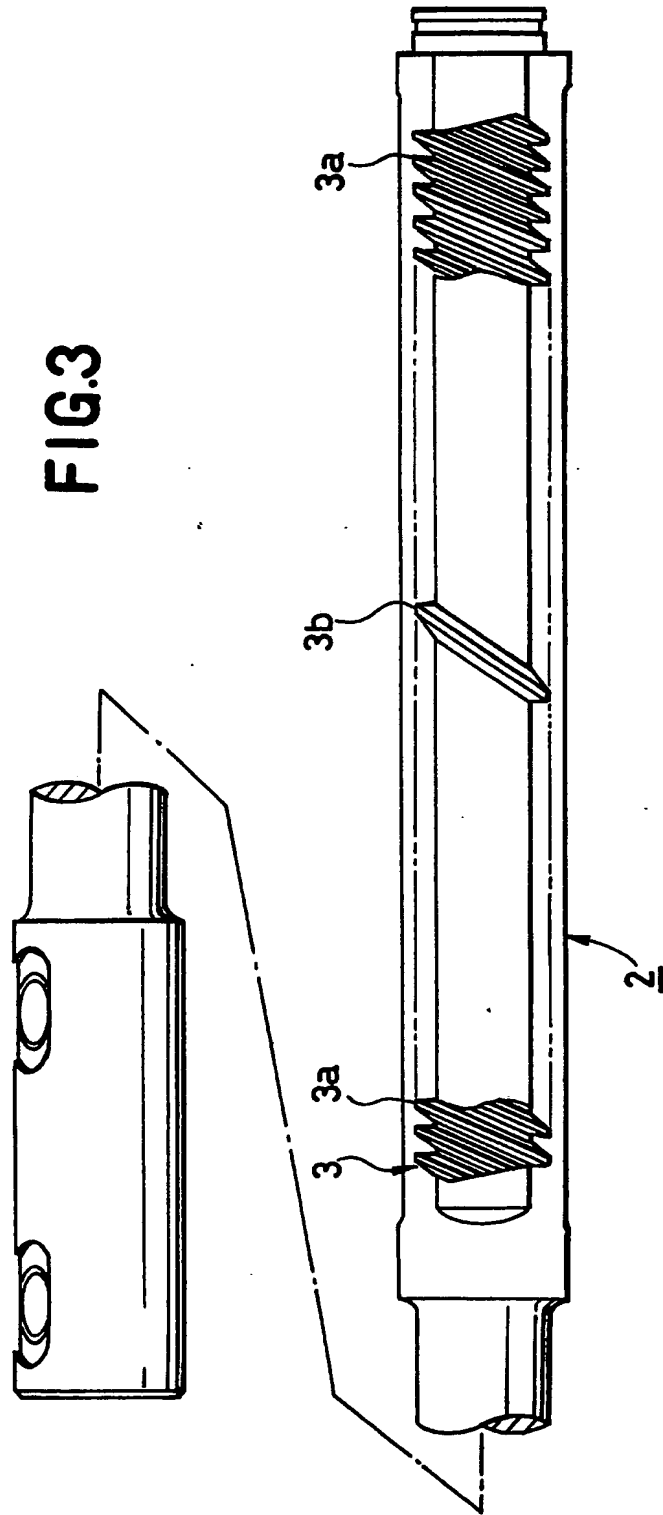


FIG.9

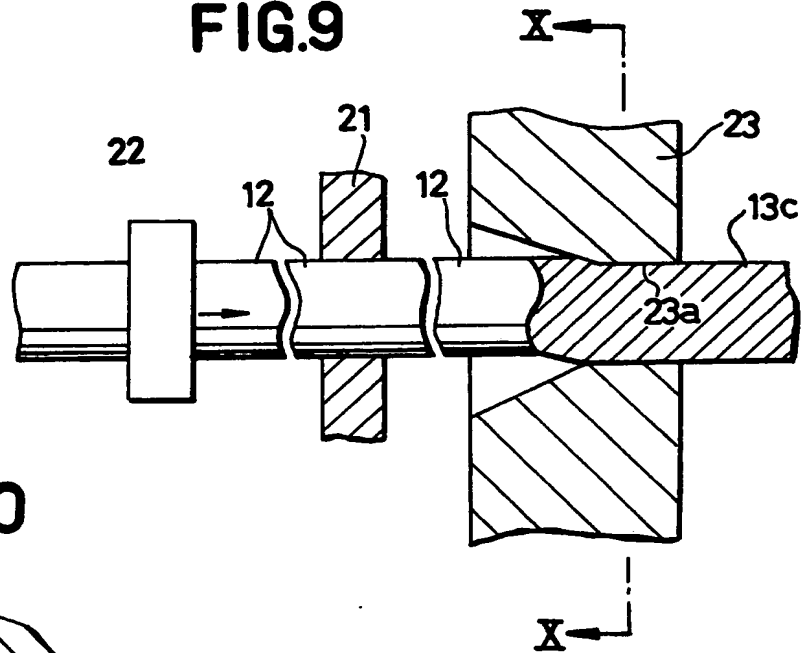


FIG.10

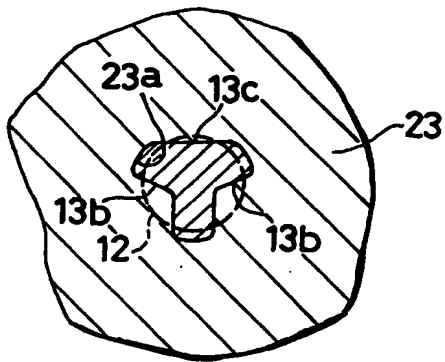


FIG.4

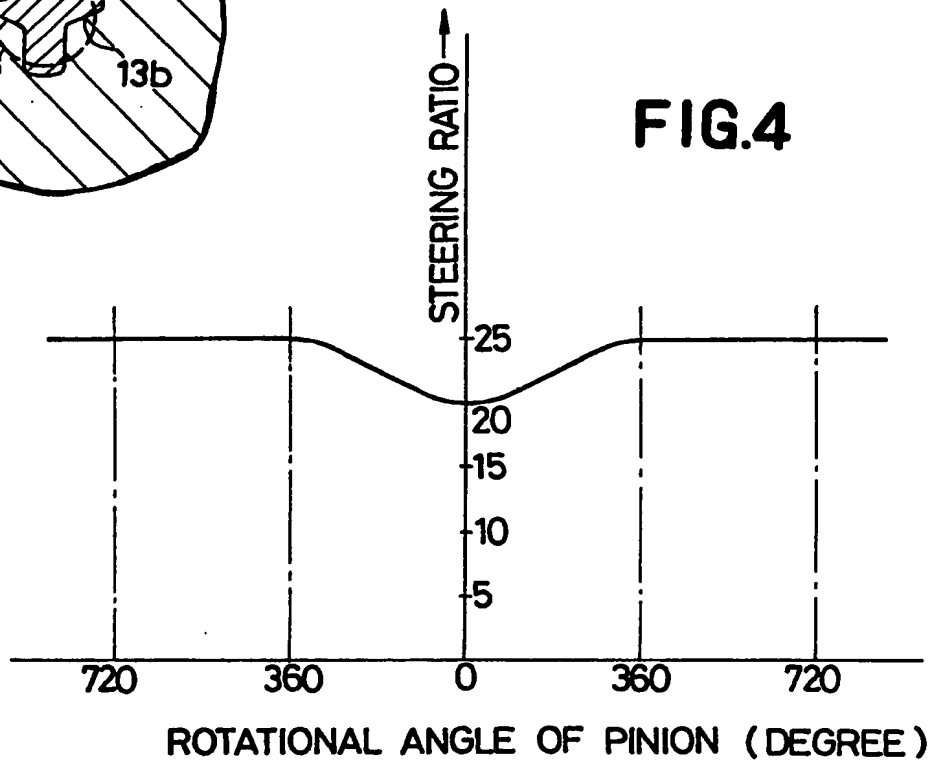


FIG.5

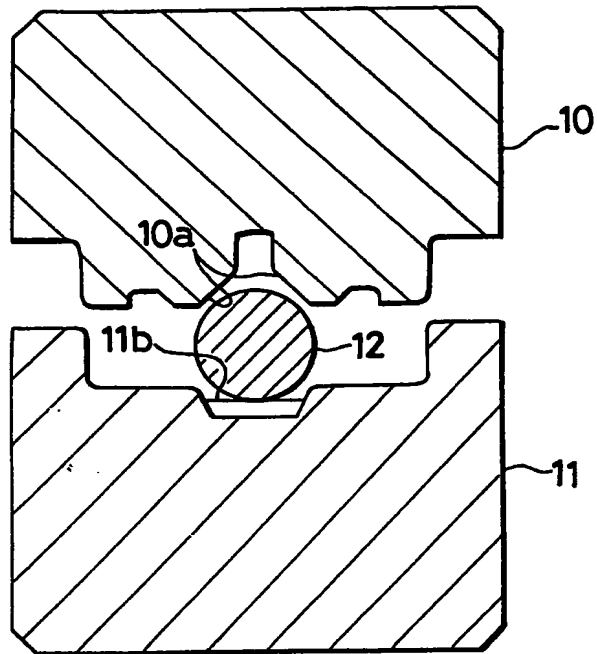


FIG.7

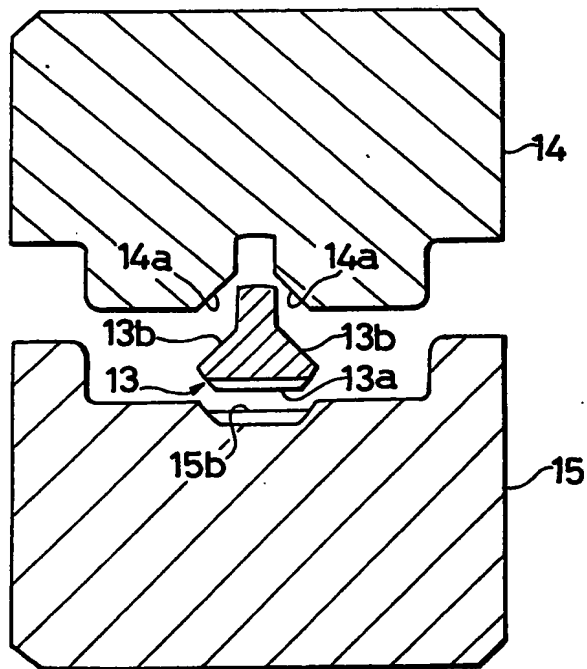


FIG.6

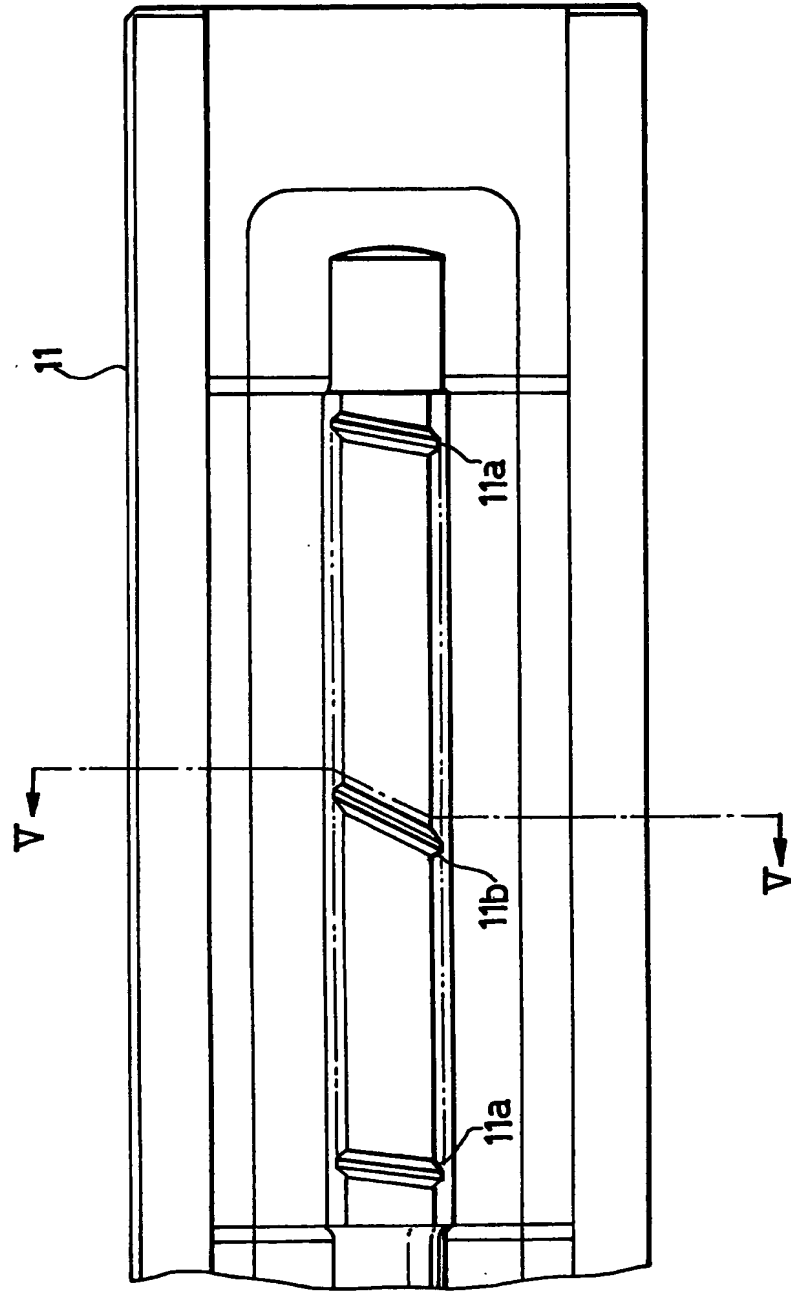
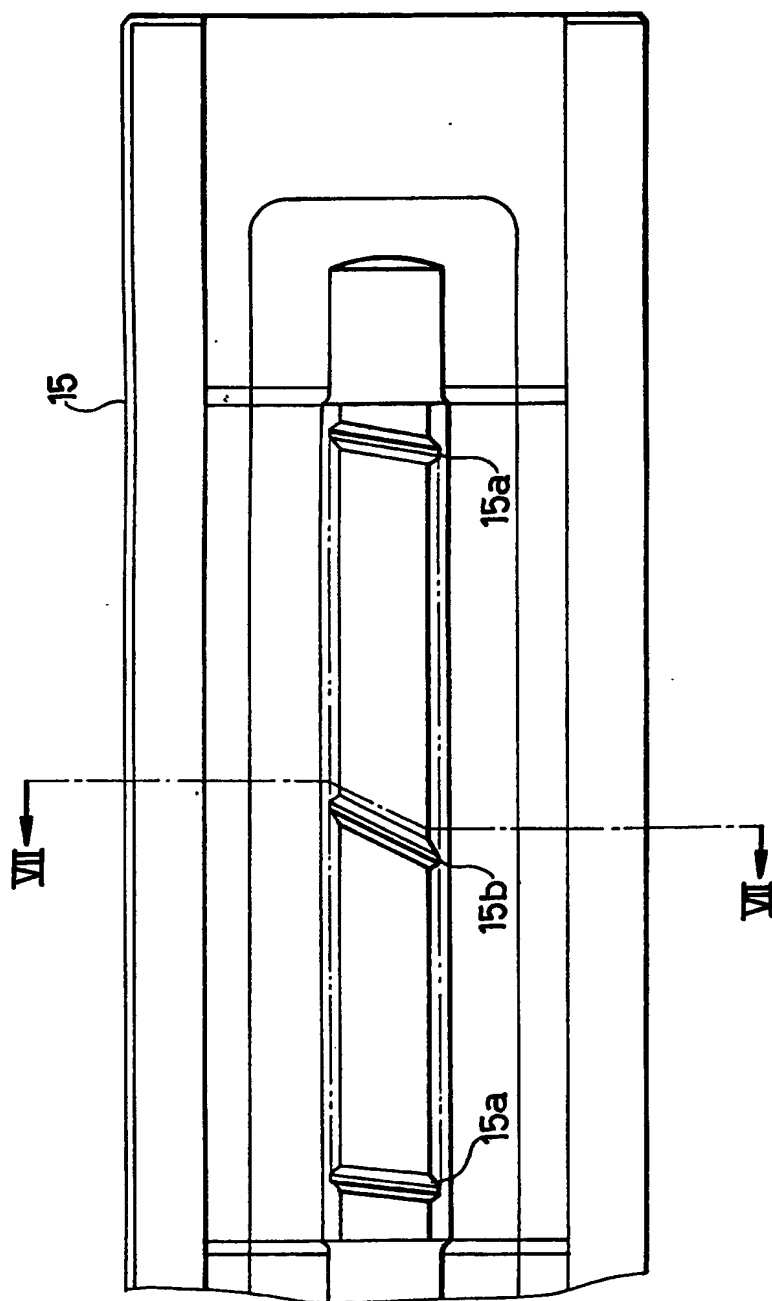


FIG.8



## SPECIFICATION

## Method for manufacturing toothed racks

This invention relates to a method for manufacturing toothed racks. More particularly, the invention relates to a method which is suitable for manufacturing variable ratio racks that may be used for steering devices of rack and pinion type.

In the conventional art, as the rack and pinion steering device of variable steering ratio type, those employing variable ratio racks are well known and disclosed, for example, in the specification of U.S. Patent No. 3,753,378. This variable ratio rack has straight rack teeth on both sides and curved rack teeth in the middle portion of the rack. The configuration of the curved teeth in the middle portion is described in detail in the foregoing patent specification and with such rack teeth, a smaller or larger steering ratio as compared with the straight rack teeth in both side portions, can be obtained.

The above variable ratio rack can be made one by one or on a small scale, however, the mass-production of the above racks is not always easy. There is proposed in Australian Laid-Open Patent Publication AU-A1 33584/78 a machine for manufacturing variable racks, with which machine the broaching close to the final shape of the rack teeth of the variable ratio rack can be attained. In order to form the final shape, however, it is still necessary to manufacture one by one or on a small scale.

It is, therefore, the primary object of the present invention to propose an improved method for manufacturing racks which are free from the above-described disadvantages in the conventional art.

Another object of the invention is to propose a method for manufacturing racks which method is capable of producing easily and in large quantities the variable ratio racks having the above-mentioned curved teeth as well as those having straight teeth.

The method of the present invention is characterized in that the method comprises a first step to form rack teeth which resemble the shape of rack teeth to be formed in a rack blank or workpiece and a second step to forge the rack teeth formed in said first step into the shape which is substantially the same as the final shape of rack teeth to be produced. In the present invention, since the rack teeth which resemble the shape of final rack teeth are formed in the first step and they are forged into the final rack teeth in the second step, the shape of rack teeth can freely be selected. Accordingly, the mass-production of curved-rack teeth as well as straight rack teeth with quite a high degree of accuracy becomes possible.

A forging process like that in the second step can be applied to the first step to form the rack teeth resembling the final rack teeth to be produced. In the case that both first and second steps are carried out by forging, the yield rate of material can be raised, and when the rear side of

the rack teeth is made Y-shape in cross-section so as to increase the rigidity of the rack, the formation of Y-shape section can be attained simultaneously with the above-mentioned forging step. Therefore, simplification of production process is possible.

As another example of the first step, the preliminary shape of the rack teeth may be formed by the broach blade that is disclosed in the foregoing Australian Patent Specification. Even in such a case, if the above Y-shaped cross-section is to be provided, the plane surface to be applied with rack teeth cutting and the Y-shaped portion on the rear side may be formed by using an upper die and lower die through forging, before the step of tooth cutting. In a further case, such a shape can be formed by means of extrusion. As compared with the cutting, the formation of the above plane portion and Y-shaped section can be performed with good yield by means of the forging or extrusion molding.

These and other objects and features of the invention will become more apparent from the following description taken in connection with the accompanying drawings, in which:

Fig. 1 is a cross-sectional plan view of a known rack and pinion steering device of variable steering ratio type;

Fig. 2 is a vertical cross-sectional view of the same taken along the line II—II in Fig. 1;

Fig. 3 is an enlarged plan view of the variable ratio rack which is used for the rack and pinion steering device as shown in Figs. 1 and 2;

Fig. 4 is a graph showing the characteristic curve of the changes of steering ratios;

Fig. 5 is a cross-sectional view of an upper die and a lower die which are used in the first step of an example of the method of the present invention and taken along the line V—V in Fig. 6;

Fig. 6 is a plan view of the lower die shown in Fig. 5;

Fig. 7 is a cross-sectional view of an upper die and a lower die which are used in the second forging step and taken along the line VII—VII in Fig. 8;

Fig. 8 is a plan view of the lower die shown in Fig. 7;

Fig. 9 is a cross-sectional view showing the state of extrusion molding in another example of the method of the present invention; and

Fig. 10 is a cross-sectional view taken along the line X—X in Fig. 9.

Referring now to the accompanying drawings, the present invention will be described in more detail by way of example.

The variable ratio rack that is shown in Fig. 3 is mounted on the rack and pinion type steering device that is shown in Figs. 1 and 2. The variable ratio rack 2 is slidably fitted in a casing 1. The rack teeth 3 of the rack 2 mesh with a helical pinion 4 which interlocks with a steering wheel (not shown). As shown in Fig. 2, the rear side of the rack teeth 3 is in the form of Y-shape in cross-section. The inclined faces 2a of the rack 2 are brought into slidable engagement with the

respective side guide surfaces 5a of a cylindrical member 5. This cylindrical member 5 is slidably fitted in the above-mentioned casing 1 and the former is movable in the direction perpendicular to the axis of the variable ratio rack 2. A spring 6 urges the cylindrical member 5 so that the rack teeth 3 are pushed toward the helical pinion 4. As shown in Fig. 3, the rack teeth 3 consists of straight rack teeth 3a in both side portions and curved rack teeth 3b in the middle portions. The configuration of these curved rack teeth 3b is described in detail in the foregoing U.S. Patent Specification. The smaller or larger steering ratio as compared with both side rack teeth 3a can be obtained by these curved rack teeth 3b, as shown in Fig. 4.

In the following, the method for manufacturing the above variable ratio rack 2 will be described.

In this method described herein, the forging process similar to the second step is employed in the first step to form the rack teeth which resemble the final rack teeth to be formed: In the first place, a round steel rod having a predetermined diameter is cut into predetermined lengths in a cutting step to make rack stocks. After the heat treatment of these rack stocks to unify the metal structure, they are subjected to hot forging. Shown in Fig. 5 are the cross-sections of upper die 10 and lower die 11 that are used for this hot forging. The plan view of the lower die 11 is shown in Fig. 6. These dies 10 and 11 are so shaped as to forge the rack stock 12 into the configuration which resembles the final shape of the rack to be produced. The lower die 11 is provided with a teeth forming portion 11a to form the above-mentioned rack teeth 3a and 3b. Meanwhile, the upper die 10 is provided with inclined portions 10a so as to form the inclined faces 2a on both sides of the Y-shaped cross-section in the rack blank 12.

When the rack stock 12 is subjected to the forging operation with using the upper die 10 and the lower die 11, the rack stock 12 made of round rod is formed into a rack stock 13 which has rack teeth 13a resembling the shape of final rack teeth 3 and inclined portions 13b as shown in Fig. 7. This rack stock 13 is then subjected to appropriate heat treatment such as annealing so as to relieve the internal stress and to unify the structure of metal. After the heat treatment, cold forging is further carried out. Shown in Fig. 7 are the cross-sections of an upper die 14 and a lower die 15 which are used for this cold forging, and in Fig. 8, a plan view of the lower die 15. These upper and lower dies 14 and 15 are basically the same as the foregoing upper and lower dies 10 and 11 for the hot forging operation. However, it should be noted that the inclined portions 14a and the teeth forming portions 15a and 15b are so shaped as to form the final configurations of the rack teeth 3a and 3b and inclined faces 2a of variable ratio rack 2. Accordingly, when the rack stock 13 is subjected to forging operation with the upper die 14 and lower die 15, the substantially completed rack teeth 3a and 3b and inclined faces 2a can be

formed.

After the above cold forging operation, heat treatment is again carried out so as to relieve the internal stress and to unify the structure of metal, which is followed by deflashing. Further, screw holes for attaching or grooves for stopper rings are formed in both end portions of the product. After that, heat treatment such as quenching and tempering, induction heat treatment, and straightening, buffing, and grinding of cylindrical surface are performed in their order, which are followed by magnetic flaw-inspection and final inspection to complete the whole manufacturing process.

In the above example, the rack teeth 13a and inclined faces 13b which resemble the final shapes are formed in the round steel 12 by means of hot forging, however, they may of course be formed by cutting.

In the following example, the rack teeth 13a are formed by cutting, while the inclined faces 13b are formed by extrusion in place of cutting. Fig. 9 shows the stage of extrusion, in cross-sectional view. Fig. 10 is the cross-sectional view taken along the line X—X in Fig. 9. A round rod rack stock 12 is inserted into a die 23 and is supported at its middle portion by a supporting member 21 for preventing buckling from occurring. In this state, the end portion of the round rod rack stock 12 is pressed in the direction of the arrow by a ram 22. The front face of the die 23 has an extrusion aperture 23a in a predetermined configuration. Accordingly, the front end of rack stock 12 is forced into the aperture 23a of die 23 by the force of ram 22 and the cross-section of the stock 12 is formed into the shape of the aperture 23a in the extrusion operation. In this case, the cross-section of the aperture 23a, that is, the cross-section of extruded rack stock comprises a plane portion 13c to form the rack teeth 13a on one side and inclined portions 13b on both sides opposite to the plane portion 13c.

After the plane portion 13c and inclined portions 13b are formed in the rack stock 12 by extrusion, the straightening of the rack stock is performed, which is followed by the heat treatment such as annealing to relieve internal stress and to unify the structure of metal. The rack teeth 13a resembling the shape of final rack teeth 3 are then formed by cutting. The formation of these rack teeth 13a can be carried out by the device disclosed in the foregoing Australian Patent Specification, so that detailed description thereof is omitted herein.

The thus obtained rack stock 13 is then subjected to deflashing to remove the flashes formed by the teeth cutting. After that, the cold forging just like the foregoing example is carried out to produce finished products.

Further, it should of course be noted that, as the method for forming the above-mentioned plane portion 13c and inclined portions 13b in the rack stock 12, the following method can also be employed. That is, the forging can be carried out by using lower dies in which teeth forming

portions 11a, 11b, 15a and 15b is omitted from the lower dies 11 and 15 that are shown in Figs. 5 and 8, and the upper dies 10 and 14 as shown in Figs. 5 and 7.

- 5 Although the present invention has been described in connection with preferred examples thereof, many variations and modifications will now become apparent to those skilled in the art.

#### CLAIMS

- 10 1. A method for manufacturing toothed racks which comprises a first step to form, in a workpiece rack teeth in a preliminary or roughened form resembling the configuration of the final rack teeth to be formed, and a second  
15 step in which by a forging operation said rack teeth formed in said first step are given a shape substantially the same as the final rack teeth to be formed.

2. The method as claimed in claim 1, wherein  
20 said racks are variable ratio racks which have straight rack teeth and curved rack teeth.

3. A method for manufacturing toothed racks which comprises a first forging step to form rack teeth by forging, in a workpiece, rack teeth  
25 resembling the configuration of the final rack teeth to be formed, and a second forging step to forge said rack teeth formed in said first forging step into the shape substantially the same as the final rack teeth to be formed.

- 30 4. The method as claimed in claim 3, wherein said racks are variable ratio racks which have straight rack teeth and curved rack teeth.

5. The method as claimed in claim 3 or claim 4, wherein the side opposite to rack teeth is  
35 simultaneously formed into a substantially Y-shape cross-section in said first forging step.

6. A method for manufacturing toothed racks which comprises a first step in which there is a forging step to forge a workpiece so as to form a  
40 plane surface for making rack teeth in the predetermined side of said workpiece and simultaneously to form the side opposite to said plane surface into a substantially Y-shape cross-section and further forming inclined surfaces to  
45 both sides thereof, said first step further including a tooth cutting step to form rack teeth by cutting in said plane surface, said rack teeth resembling the configuration of the final rack teeth to be formed, and a second forging step to forge said  
50 rack teeth into the shape substantially the same as the final rack teeth to be formed.

7. The method as claimed in claim 6, wherein said racks are variable ratio racks which have  
55 straight rack teeth and curved rack teeth.

8. A method for manufacturing toothed racks which comprises a first step in which a workpiece is subjected to an extrusion step so as to form a plane surface for making rack teeth in the  
60 predetermined side of said workpiece and simultaneously forming the side opposite to said plane surface into Y-shape in cross-section and further forming inclined surfaces to both sides thereof, said first step further including a tooth cutting step to form rack teeth by cutting in said

- 65 plane surface, said rack teeth resembling the configuration of the final rack teeth to be formed, and a second forging step to forge said rack teeth into the shape substantially the same as the final rack teeth to be formed.

- 70 9. The method as claimed in claim 8, wherein said racks are variable ratio racks which have straight rack teeth and curved rack teeth.

10. A method for manufacturing toothed racks substantially as described herein with reference to  
75 the examples illustrated in the accompanying drawings.

11. A toothed rack when manufactured by the method of any one of the preceding claims.

- New claims or amendments to claims filed on 26  
80 November 1981.

Superseded claims 1—11.

New or amended claims:— 1—14.

1. A method of manufacturing toothed racks wherein there is a metal-forming step in which  
85 one side of a workpiece is given a preparatory shape for configuration of the rack teeth and the opposite side of the workpiece is given a substantially Y-shape cross-section, and there is a subsequent forging step in which the rack teeth  
90 are formed to substantially their final configuration on said one side of the workpiece.

2. A method according to claim 1 wherein said metal-forming step is a forging step in which the rack teeth are formed to a preliminary  
95 configuration.

3. A method according to claim 1 wherein in said metal-forming step said one side of the workpiece is formed as a plane surface and a  
100 tooth-cutting step is performed on said surface before said subsequent forging step.

4. A method according to claim 3 wherein said metal-forming step is a forging step.

5. A method according to claim 3 wherein said metal-forming step is an extruding step.

- 105 6. A method according to any one of the preceding claims wherein said rack is a variable ratio rack having straight rack teeth and curved rack teeth.

7. A method of manufacturing toothed racks in  
110 which there is a first forging step comprising forming on one side of a workpiece rack teeth resembling the configuration of the final rack teeth to be formed, and simultaneously forming the side opposite to said rack teeth into a substantially  
115 Y-shape cross-section step, and a second forging step to forge said rack teeth formed in said first forging step into the shape substantially the same as the final rack teeth to be formed.

8. The method as claimed in claim 7, wherein  
120 said rack is a variable ratio rack which has straight rack teeth and curved rack teeth.

9. A method of manufacturing toothed racks which comprises a first step in which there is a forging step to forge a workpiece so as to form a  
125 plane surface for making rack teeth in the predetermined side of said workpiece and simultaneously to form the side opposite to said

- plane surface into a substantially Y-shape cross-section and further forming inclined surfaces to both sides thereof, said first step further including a tooth cutting step to form rack teeth by cutting
- 5 in said plane surface, said rack teeth resembling the configuration of the final rack teeth to be formed, and a second forging step to forge said rack teeth into the shape substantially the same as the final rack teeth to be formed.
- 10 10. The method as claimed in claim 9, wherein said rack is a variable ratio rack which has straight rack teeth and curved rack teeth.
- 15 11. A method of manufacturing toothed racks which comprises a first step in which a workpiece is subjected to an extrusion step so as to form a plane surface for making rack teeth in the predetermined side of said workpiece and simultaneously forming the side opposite to said
- plane surface into Y-shape in cross-section and further forming inclined surfaces to both sides thereof, said first step further including a tooth cutting step to form rack teeth by cutting in said plane surface, said rack teeth resembling the configuration of the final rack teeth to be formed,
- 20 and a second forging step to forge said rack teeth into the shape substantially the same as the final rack teeth to be formed.
- 25 12. The method as claimed in claim 11, wherein said rack is a variable ratio rack which has straight rack teeth and curved rack teeth.
- 30 13. A method of manufacturing toothed racks substantially as described herein with reference to the examples illustrated in the accompanying drawings.
- 35 14. A toothed rack when manufactured by the method of any one of the preceding claims.